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RESEARCH ARTICLE

Phytoliths from some grasses (Poaceae) in arid lands of Xinjiang, China

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Abstract

Opal phytoliths, as silicon dioxide inclusions, are abundant in different parts of a plant. It is known that grasses are the most representative in this respect. The research of phytoliths, removed from 25 most common grass species in the arid and semiarid lands of the Junggar Basin and adjacent areas, has been undertaken. The visual estimation of diversity and variability of silica cells and identification of their morphological types (patterns) were also the aim of our research. Since the work is preliminary, we have emphasized on the visual estimation of silica cell variability and involved only the leaf blades in the analysis. Drawings of the revealed silica cells, characteristic of 25 species, are provided. The significant morphological diversity of phytoliths has been revealed, as well as their taxonomic similarity at the level of subfamilies. These data can be used for the identification of phytoliths from sediments.

Keywords

Central Asia, deserts, plant anatomy, silicon dioxide inclusion

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Introduction

Increasing attention of contemporary science is given to the study of phytoliths. Phytoliths are silicon dioxide inclusions abundant in different parts of a plant. Silicon, being dissolved in underground water, can be adsorbed by plants, and then it is deposited between the cell walls as opal. It can impregnate the cellular walls or fill the plant cells completely and may be dispersed in leaves, roots, stems, and even seeds. As for grasses, they are concentrated mainly in the epidermis (Krishnan et al. 2000). The phytoliths increase the plant density, support the vertical position of stems, promote the absorption of sunlight for photosynthesis, serve as protection against fungal infection, and also make plants less attractive to herbivores, rodents, and insects (Lu et al. 2002; Lu and Liu 2003a; Myrlian and Medyanik 2008).

During the last 30 years, grass phytoliths together with pollen grains, are widely used for stratification, as well as paleobotanical and paleogeographic reconstructions (Witty et al. 1964; Kurmann 1985; Fisher et al. 1995; Blinnikov 2005). In fact, grass phytoliths have a number of advantages over pollen grains in terms of their use in paleogeography. Being composed of silicon, phytoliths are more resistant to destruction than pollen or spores of vascular plants. Their inorganic origin makes them denser than organic remains. They have a greater density than other fossils of plants and keep their morphological features after the plant dies off. Phytoliths are transferred by winds or water streams much less than pollen grains, and they usually remain and deposit near a parent plant after decomposition (Myrlian and Medianic 2008). Pollen grains usually do not vary significantly in their shapes, whereas phytoliths essentially vary both in their sizes and shapes, corresponding to certain plants taxa, and help to date the time of grass diversification (Stromberg 2004) and vegetation of past epochs. Phytoliths are successfully used in paleoclimatology (Twiss 1987; Liu et al. 1995; Lu et al. 2006), paleogeography, and soil science (Wu et al. 1992; Golyeva 1995; Contreras et al. 2019). Besides, phytoliths, found in the sediments of archeologic sites, are applied to define agricultural and cattle-breading activities of ancient people and to identify plants used by people in ancient and prehistoric periods (Elbaum et al. 2003; Delhon 2008; Piperno 2006; Wang et al. 2018; Danu et al. 2019). Indeed, in accordance with Rosen et al. (2008), phytolith analysis is one of the most versatile archaeobotanical techniques used in archaeology and paleoenvironmental analysis. Besides listing the most common ways of uses of phytoliths, they mentioned some less traditional ones, such as the evidence for both natural and human-induced fire ecology by distinguishing phytoliths from burned material versus those from unburned deposits; analysis of phytolith properties indicating irrigation agriculture in alluvial valleys versus dry-farming in interfluvial settings; reconstructing climatic records from carbon and oxygen isotopes found respectively within organic matter occluded inside phytoliths, and oxygen from the SiO_2 itself. Regardless of the fact that phytoliths of many grasses are quite similar, they can be used successfully for vegetation reconstructions and specification of floristic characteristics (Patterer et al. 2013). Piperno (1988) has underlined that

genus level identification is not necessary for accurate and informative reconstructions of grass ecosystems. Many researchers (Golyeva 1995; Blinnikov 2005; Neto et al. 2018) use the whole phytolith complexes, which serve as indicators of different phytocenosis, for stratification, dating, and reconstruction of vegetation changes.

The aim of our research was a preliminary visual estimation of phytolith types and their diversity in investigated species, to reveal the specific morphological types, corresponding to certain taxa of grasses, and to make the special tables of phytoliths types of these species. We have undertaken an attempt to extract phytoliths from leaves of 25 most common grass species in the arid and semiarid lands of the Junggar Basin and adjacent areas of Xinjiang, China. Since the work is preliminary, we investigated only the leaf blades and have emphasized on the visual estimation of silica cell variability. These results can be used for the identification of phytoliths from sediments. The phytoliths complexes usually used for vegetation reconstructions, consist of phytoliths of different plant species. The more species are involved in the study and the better phytolith research is carried out, the more reliable the reconstructions will be.

Material and methods

The study area covers the Northern part of Xinjiang province (Fig. 1), approximately between 45–48° N and 86–90° E and is characterized by elevations failing within (-83) 300–600 m (Table 1), where dry arid climate take place (Lo 1957; Zhan et al. 1957). Murzayev (1966) shows the annual mean temperature for this area 6–8 °C, (average temperature of July 24–26 (34) °C, January 18–20 °C below zero) and annual precipitation (50) 100–300 mm. It caused the formation of dry steppes and deserts there (Hou 1988; Ni 2001), where arid grasses are common. Nevertheless, due to the high diversity of habitats, species that are common in semiarid communities may occur also in deserts, when meeting the appropriate conditions. This territory was chosen on the one side, because being rich in grasses of different subfamilies, and phytoliths of different systematic groups could be extracted and compared. On the other side, because the arid and semiarid lands are quite common there, it was possible to identify the main types of grass phytoliths, characteristic for plant communities of arid and semiarid territories. Grasses were collected in the summer of 2010 by M. Olonova and Duan Shimin in arid and semiarid plant communities (TK). The map was constructed using ArcGIS software (ESRI, 2012).

A total of 25 grass species (52 samples) have been studied. All selected samples were in a phase of flowering, with well-developed flag leaves and similar morphological type of species. The stems and leaves were studied.

Samples are stored in the Herbarium of Tomsk State University (TK). Three to five individuals were selected from each population. The phytoliths were removed from leaves by the method of Piperno (1988). The samples were placed in porcelain crucibles, then into a muffle furnace, and ignited at 500 °C for 2 hours. Then they

were allowed to cool and washed with 10% HCl, concentrated nitric acid, and finally distilled water. The phytoliths were placed in glass bottles and then were examined under a microscope and photographed. The research of silica cells was carried out by means of a hardware-software complex SIAMS MesoPlant, which includes a specialized computer, microscope Axiostar, the scanner, and digital video camera SIMAGIS 2M-75. The epidermis of all samples was observed in a light microscope in order to have a notion about its construction.

The morphological types of phytoliths were recognized in accordance with the classification of Powers-Jones and Padmore (1993) and Lu and Liu (2003b). The recommendations, stated in the International Code of the Nomenclature of Phytoliths (Madella et al. 2005) have been taken into account as well.

Table 1. The samples, used for phytoliths extraction (TK)

№	Species	Location
1	*Stephanachne pappophorea*	China, Xinjiang, along the road Urumqi – Fuyun, N 45°05', E 89°16', rocky desert, on the dry brook bed, 08.09.2010. M. Olonova, Duan Shimin (TK)
2	*Piptatherum songaricum* (Trin. et Rupr.) Roshev.	China, Xinjiang, Irtysh river head, N 47°12', E 89°49', stony steppe slope, 09.09.2010. M. Olonova, Duan Shimin (TK)
3	*Piptatherum songaricum*	China, Xinjiang, near Altai Forest park, N 47°57', E 88°11', stepped slope, 10.09.2010. M. Olonova, Duan Shimin (TK)
4	*Piptatherum songaricum*	China, Xinjiang Altai mountains, N 48°38', E 87°02', stepped slope, 10.09.2010. M. Olonova, Duan Shimin (TK)
5	*Stipa sareptana*	China, Xinjiang, near Altay, N 47°58' E 88°11', steppe desert, 10.09.2010. M. Olonova, Duan Shimin (TK)
6	*Stipa glareosa*	China, Xinjiang, near Altay, N 47°58' E 88°11', steppe desert, 10.09.2010. M. Olonova, Duan Shimin (TK)
7	*Stipa glareosa*	China, Xinjiang, along the road Urumqi – Fuyun, N 45°05', E 89°16', rocky desert, 08.09.2010. M. Olonova, Duan Shimin (TK)
8	*Stipa glareosa*	China, Xinjiang, Altai mountains, N 47°12', E 89°48' steppe desert, 10.09.2010. M. Olonova, Duan Shimin (TK)
9	*Ptilagrostis pellioti*	China, Xinjiang, along the road Urumqi – Turpan, near wind power-station, shrub desert, 2.10.2010. M. Olonova, Duan Shimin (TK)
10	*Achnatherum splendens* (Trin.) Nevski	China, Xinjiang, along the road Urumqi – Fuyun, N 45°05', E 89°16', rocky desert, 08.09.2010
11	*Achnatherum splendens*	China, Xinjiang, along the road Urumqi – Fuyun, N 47°12', E 89°48', steppe desert, 09.09.2010. M. Olonova, Duan Shimin (TK)
12	*Achnatherum splendens*	China, Xinjiang, bank of Irtysh river, near the bridge, N 47°52', E 89°17', rocky steppe desert, 12.09.2010. M. Olonova, Duan Shimin (TK)

№	Species	Location
13	*Achnatherum caragana* (Trin.) Nevski	China, Xinjiang, near Altay, N 47°58' E 88°11', steppe desert, 10.09.2010. M. Olonova, Duan Shimin (TK)
14	*Achnatherum caragana*	China, Xinjiang, Altay mountains, N 47°51', E 88°12' steppe desert on the top of the mountain, 10.09.2010. M. Olonova, Duan Shimin (TK)
15	*Achnatherum caragana*	China, Xinjiang, N 47°33', E 88°25', steppe desert, 13.09.2010
16	*Melica transilvanica*	China, Xinjiang, Irtysh river head, N 47°12', E 89°49', stony stepped slope, 09.09.2010. M. Olonova, Duan Shimin (TK)
17	*Melica transsilvanica*	China, Xinjiang, near Altai Forest park, N 47°57', E 88°11', stepped slope, 10.09.2010. M. Olonova, Duan Shimin (TK)
18	*Melica transsilvanica* Schur	China, Xinjiang Altai mountains, N 48°38', E 87°02', stepped slope, 10.09.2010. M. Olonova, Duan Shimin (TK)
19	*Polypogon monspeliensis* (L.) Desf.	China, Xinjiang, bank of Irtysh River, near the bridge, N 47°52', E 86°17', steppe desert, among the shrubs, 12.09.2010. M. Olonova, Duan Shimin (TK)
20	*Bromus squarrosus* L.	China, Xinjiang, along the road Urumqi – Fuyun, N 45°05', E 89°16', rocky desert, among the shrubs, 08.09.2010. M. Olonova, Duan Shimin (TK)
21	*Bromus squarrosus*	China, Xinjiang, along the road Urumqi – Fuyun, N 45°05', E 89°16', rocky desert, on the dry brook bed, 08.09.2010. M. Olonova, Duan Shimin (TK)
22	*Bromus squarrosus*	China, Xinjiang, bank of Irtysh River, near the bridge, N 47°52', E 86°17', steppe desert, among the shrubs, 12.09.2010. M. Olonova, Duan Shimin (TK)
23	*Leymus racemosus* (Lam.) Tzvel.	China, Xinjiang, N 48°21'N, E 85°45', sandy desert, 12.09.2010. M. Olonova, Duan Shimin (TK)
24	*Leymus racemosus*	China, Xinjiang, along the road Urumqi – Fukang, sandy desert, 08.09.2010. M. Olonova, Duan Shimin (TK)
25	*Leymus secalinus* (Georgi) Tzvel.	China, Xinjiang, Irtysh River head, N 47°12', E 89°49', stony stepped slope, 09.09.2010. M. Olonova, Duan Shimin (TK)
26	*Leymus secalinus*	China, Xinjiang, near Altai Forest park, N 47°57', E 88°11', stepped slope, 10.09.2010. M. Olonova, Duan Shimin (TK)
27	*Psathyrostachys juncea*	China, Xinjiang, near Altay, N 47°58' E 88°11', steppe desert, 10.09.2010. M. Olonova, Duan Shimin (TK)
28	*Psathyrostachys juncea*	China, Xinjiang, Altai mountains, N 47°12', E 89°48', stepped desert, 10.09.2010. M. Olonova, Duan Shimin (TK)
29	*Psathyrostachys juncea*	China, Xinjiang, Irtysh river head, N 47°12', E 89°49', stepped desert on the slope, 09.09.2010. M. Olonova, Duan Shimin (TK)
30	*Kengyilia hirsuta*	China, Xinjiang, along the road Urumqi – Fuyun, N 45°05', E 89°16', rocky desert, among the shrubs, 08.09.2010. M. Olonova, Duan Shimin (TK)
31	*Kengyilia kokonorica*	China, Xinjiang, along the road Urumqi – Turpan, near wind power-station, rocky desert, among the shrubs, 2.10.2010. M. Olonova, Duan Shimin (TK)

№	Species	Location
32	*Eremopyrum bonaepartis* (Spreng.) Nevski	China, Xinjiang, along the road Urumqi – Fuyun, N 45°05', E 89°16', rocky desert, 08.09.2010. M. Olonova, Duan Shimin (TK)
33	*Schismus arabicus* Nees	China, Xinjiang, along the road Urumqi – Fuyun, N 45°05', E 89°16', rocky desert, on the dry brook bed, 08.09.2010. M. Olonova, Duan Shimin (TK)
34	*Schismus arabicus*	China, Xinjiang, along the road Urumqi – Fuyun, N 47°12', E 89°48', steppe desert, 09.09.2010. M. Olonova, Duan Shimin (TK)
35	*Schismus arabicus*	China, Xinjiang, Turpan, near Turpan Botanical garden, along the water canal, 2.10.2010. M. Olonova, Duan Shimin (TK)
36	*Aristida adscensionis* L.	China, Xinjiang, Near Turpan, sandy desert, 2.10.2010. M. Olonova, Duan Shimin (TK)
37	*Aristida adscensionis*	China, Xinjiang, along the road Urumqi – Fuyun, N 45°05', E 89°16', sandy desert, 08.09.2010. M. Olonova, Duan Shimin (TK)
38	*Aristida adscensionis*	China, Xinjiang, along the road Urumqi – Fukang, sandy desert, 08.09.2010. M. Olonova, Duan Shimin (TK)
39	*Stipagrostis pennata* (Trin.) de Winter	China, Xinjiang, along the road Urumqi – Fuyun, N 45°05', E 89°16', sandy desert, 08.09.2010. M. Olonova, Duan Shimin (TK)
40	*Stipagrostis pennata*	China, Xinjiang, N 48°21', E 85°45', sandy desert, 12.09.2010. M. Olonova, Duan Shimin (TK)
41	*Stipagrostis pennata*	China, Xinjiang, N 48°03', E 85°39', sandy desert, 12.09.2010. M. Olonova, Duan Shimin (TK)
42	*Aeluropus micrantherus*	China, Xinjiang, along the road Urumqi – Fuyun, N 45°05', E 89°16', rocky desert, on the dry brook bed, 08.09.2010. M. Olonova, Duan Shimin (TK)
43	*Aeluropus pungens*	China, Xinjiang, bank of Irtysh River, near the bridge. E 47°52', E 89°17', rocky steppe desert, 12.09.2010. M. Olonova, Duan Shimin (TK)
44	*Cleistogenes squarrosa* (Trin.) Keng	China, Xinjiang, along the road Urumqi – Fuyun, N 45°05', E 89°16', rocky desert, 08.09.2010. M. Olonova, Duan Shimin (TK)
45	*Cleistogenes squarrosa*	China, Xinjiang, Altay mountains, N 47°51', E 88°12', stepped desert on the top of mountain, 09.09.2010. M. Olonova, Duan Shimin (TK)
46	*Cleistogenes squarrosa*	China, Xinjiang, along the road Urumqi – Turpan, near wind power-station, rocky desert, 2.10.2010. M. Olonova, Duan Shimin (TK)
47	*Crypsis schoenoides*	China, Xinjiang, bank of Irtysh River, near the bridge, N 47°52', E 89°17', rocky steppe desert, 12.09.2010. M. Olonova, Duan Shimin (TK)
48	*Crypsis schoenoides*	China, Xinjiang, Turpan Botanical garden, among the trees, 2.10.2010. M. Olonova, Duan Shimin (TK)

№	Species	Location
49	*Chloris virgata*	China, Xinjiang, along the road Urumqi – Turpan, near wind power-station, shrub desert, 2.10.2010. M. Olonova, Duan Shimin (TK)
50	*Chloris virgata*	China, Xinjiang, Turpan, near Turpan Botanical garden, along the road, 2.10.2010. M. Olonova, Duan Shimin (TK)
51	*Chloris virgata*	China, Xinjiang, along the road Urumqi – Fuyun, N 45°05', E 89°16', rocky desert, on the dry brook bed, 08.09.2010. M. Olonova, Duan Shimin (TK)
52	*Bothriochloa ischaemum*	China, Xinjiang, Altay mountains, N 47°51', E 88°12', steppe desert on the top of mountain, 10.09.2010. M. Olonova, Duan Shimin (TK)
53	*Bothriochloa ischaemum*	China, Xinjiang, near Altai Forest park, N 47°57', E 88°11', stepped slope, 10.09.2010. M. Olonova, Duan Shimin (TK)
54	*Bothriochloa ischaemum*	China, Xinjiang, Turpan Botanical garden, among the trees, 2.10.2010. M. Olonova, Duan Shimin (TK)

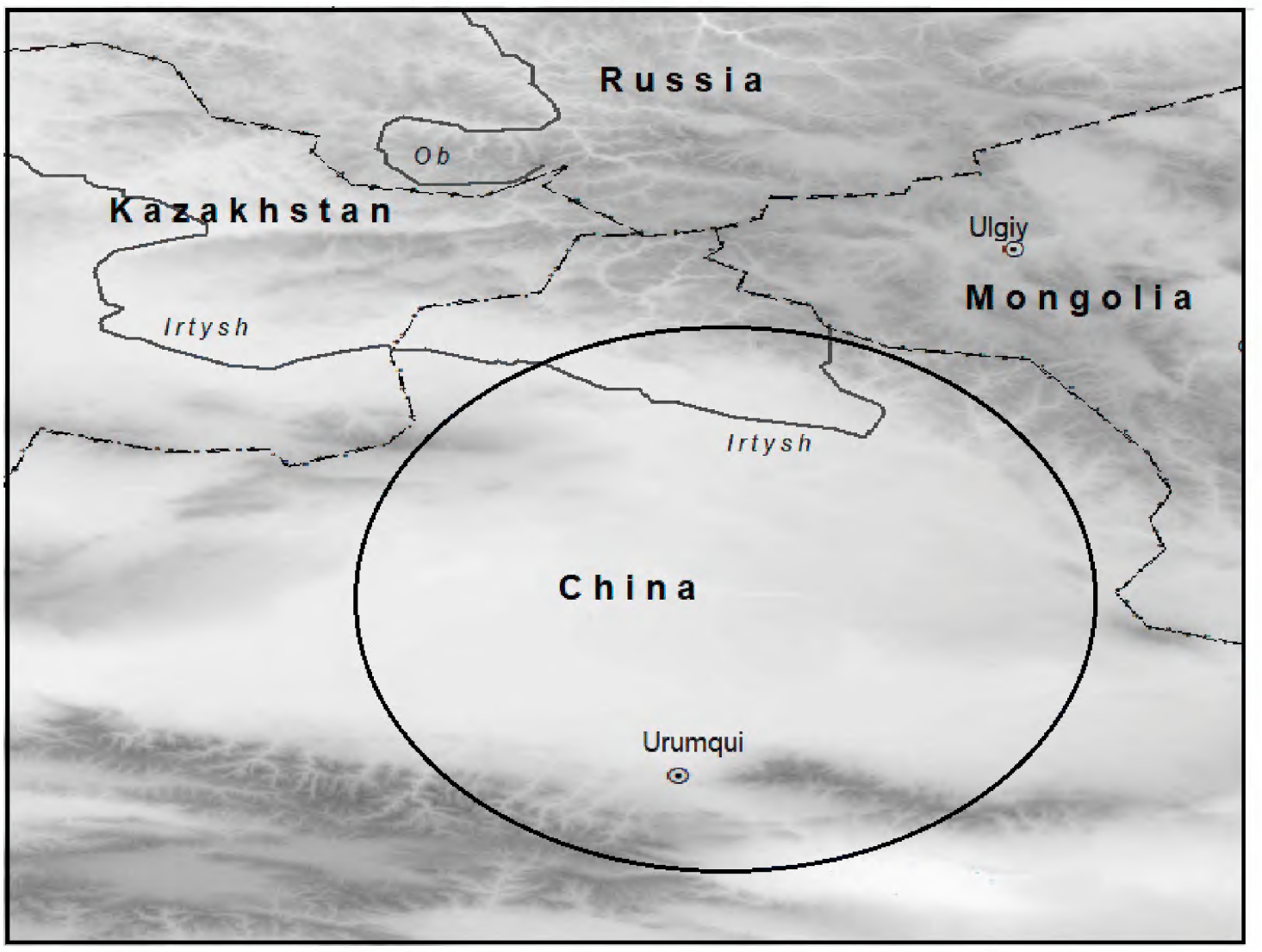

Figure 1. Map of the study area (China, Xinjiang).

Results and discussion

It is known that most grasses have a different epidermal structure between the veins of leaf blades and the rest of the area. The cells at the veins (costal zone) are usually shorter and narrower, and different kinds of trichomes are common there and stomata are usually absent (Metcalfe 1960). In the area between veins (intercostal zone) the cells are usually larger and longer, and the stomata are located here. The research has revealed the cells of both areas, impregnated with silicon, but the cells from veins are prevailing (Olonova et al. 2016). The short cells, which are also referred to as silica bodies, are of major importance in phytolith analysis because their shapes are known to be effectively conjoined with different subfamilies.

The study of morphological types of phytoliths, removed from these species, has revealed their great diversity, both in size and in shape, corresponded to their taxonomic variability. Altogether, 12 types of phytoliths have been registered (Table 2), but, since all of them seem to represent a continual sequence, the accepted division is quite relative: some of the types might be divided, and to other of them might be jointed; irregular phytoliths might be recognized among polylobate ones as well. Nevertheless, it can give a notion about phytolith diversity. The main task may hence be considered to have been fulfilled. Different types of phytoliths have been registered. There were rod, saddle, roundel, square, trapezoid, triangular, and prickles as well. Polylobate, saddle, and bilobate proved to be the most variable.

Table 2. Morphological types of phytoliths from some grasses in arid and semiarid lands of Xinjiang.

Taxa	Morphotype of phytoliths (see Fig. 2)											
	1	2	3	4	5	6	7	8	9	10	11	12
Pooideae												
Stephanachne pappophorea	-	-	-	b	a	b	-	a	a	a	-	a
Piptatherum songaricum	-	b	-	b, d	-	c	-	-	-	-	-	-
Stipa sareptana	-	-	-	-	c	h	-	a	-	a	-	a, b
Stipa glareosa	-	a	-	-	-	-	-	a	a	a	-	b
Ptilagrostis pellioti	-	-	-	-	-	-	-	a	a	a	a	a
Achnatherum splendens	-	a	-	-	-	-	-	a	-	-	-	-
Achnatherum caragana	-	-	-	c	a, b	h	-	a	a	-	a	a
Melica transsilvanica	-	a	-	c	b	-	-	a	a	a	a	a
Polypogon monspeliensis	-	a, b	-	a	c	-	-	-	-	-	a	a
Bromus squarrosus	a	a	-	-	b	-	-	a	-	-	-	-
Leymus racemosus	-	-	-	-	b	-	-	a	-	a	-	-
Leymus secalinus	-	a	-	-	a, b	-	-	-	a	a	-	a
Psathyrostachys juncea	-	-	-	b	a, c	e, b	-	a	-	-	-	a

Taxa	Morphotype of phytoliths (see Fig. 2)											
	1	2	3	4	5	6	7	8	9	10	11	12
Kengyilia hirsuta	-	a	-	b	a	b	-	a	a	a	-	a
Kengyilia kokonorica	a	a	-	c	b	b	-	a	-	a	a	a
Eremopyrum bonaepartis	a	a, b	-	-	b	d	-	a	-	-	-	a
Danthonioideae												
Schismus arabicus	-	b	-	a, b, c	b, d	e	-	-	a	-	-	a
Aristideae												
Aristida adscensionis	-	a	-	-	c, d	e, f	-	a	a	a	-	a
Stipagrostis pennata	-	a	-	b	-	e	-	-	a	-	-	a
Chloridoideae												
Aeluropus micrantherus	-	-	-	-	b,	b, h	-	-	-	-	a	a
Aeluropus pungens	-	b	-	-	b	b, h	-	-	a	-	a	a
Cleistogenes sqarrosa	-	-	-	-	-	b, e, f, g	-	a	-	-	-	a
Crypsis schoenoides	-	a	-	-	b, d	b, d	-	-	-	a	-	a
Chloris virgata	-	b	-	-	a, d	-	-	-	-	-	-	a
Panicoideae												
Bothryochloa ischaemum	-	b	a	-	-	a, d	a	-	-	-	-	-

Type of phytoliths: 1 – Smooth rods. 2 – Narrow wavy rods. 3 – Coarse wavy rods. 4 – Polylobate. 5 – Saddle. 6 – Bilobate. 7 – Quadra-lobate. 8 – Rondel. 9 – Square. 10 – Trapezoid. 11 – Triangular. 12 – Prickles. Symbols a, b, c, d, e, f, g, h denote the same as in Figure 2.

The single investigated representative of subfamily Panicoideae Link, *Botriochloa ischaemum* (L.) Keng, has proved to possess the most singular silica cells. The long cells with narrow and long folds (Fig. 2) have been found only among samples of this species (Fig. 3Y). Various lobate silica cells, including polylobate, turned to bilobate and then transformed to four-lobed characteristics for this species as well. The quadra-lobate type never occurred in others. Some similar phytoliths have been found at *Aeluropus* Trin. (subfamily Chloridoideae). Nevertheless, they cannot be recognized as exactly quadra-lobate (Fig. 3T).

The phytoliths of *Cleistogenes squarrosa* (subfamily Chloridoideae) as a whole, differed from those of all other investigated samples, being represented mainly by various kinds of bilobate cells (Figs 3V, 4). The predominance of various bilobate phytoliths was characteristic for all investigated Chloridoideae Kunth ex Beilschm., but the presence of the form with the elongated middle part (Fig. 2), besides being found at *Cleistogenes* Keng, was registered only among the samples of *Aristida adscensionis* (subfamily Aristideae C.E. Hubb.).

All samples of *Aristida adscensionis* contained bilobate cells (or dumbbells) of almost the same size, which are characteristic for an intercostal zone, small ron-

dels (orbicular), square cells, the cells of intermediate type, and pricles (Fig. 3R). A small amount of coarse wavy rods and polylobates have been found as well. At other species of this subfamily – *Stipagrostis pennata*– saddle phytoliths were prevailing, whereas bilobate ones were rarely found (Fig. 3S).

Phytoliths of *Schismus arabicus* at the single investigated representative of subfamily Danthonioideae N.P. Barker et H.P. Linder, have no unique or distinctive attributes (Fig. 3Q). The coarse wavy rods, polylobate, and saddle types were predominant ones in all samplings of this species, the last type to be rather intermediate between the typical saddle and polylobate (Fig. 2).

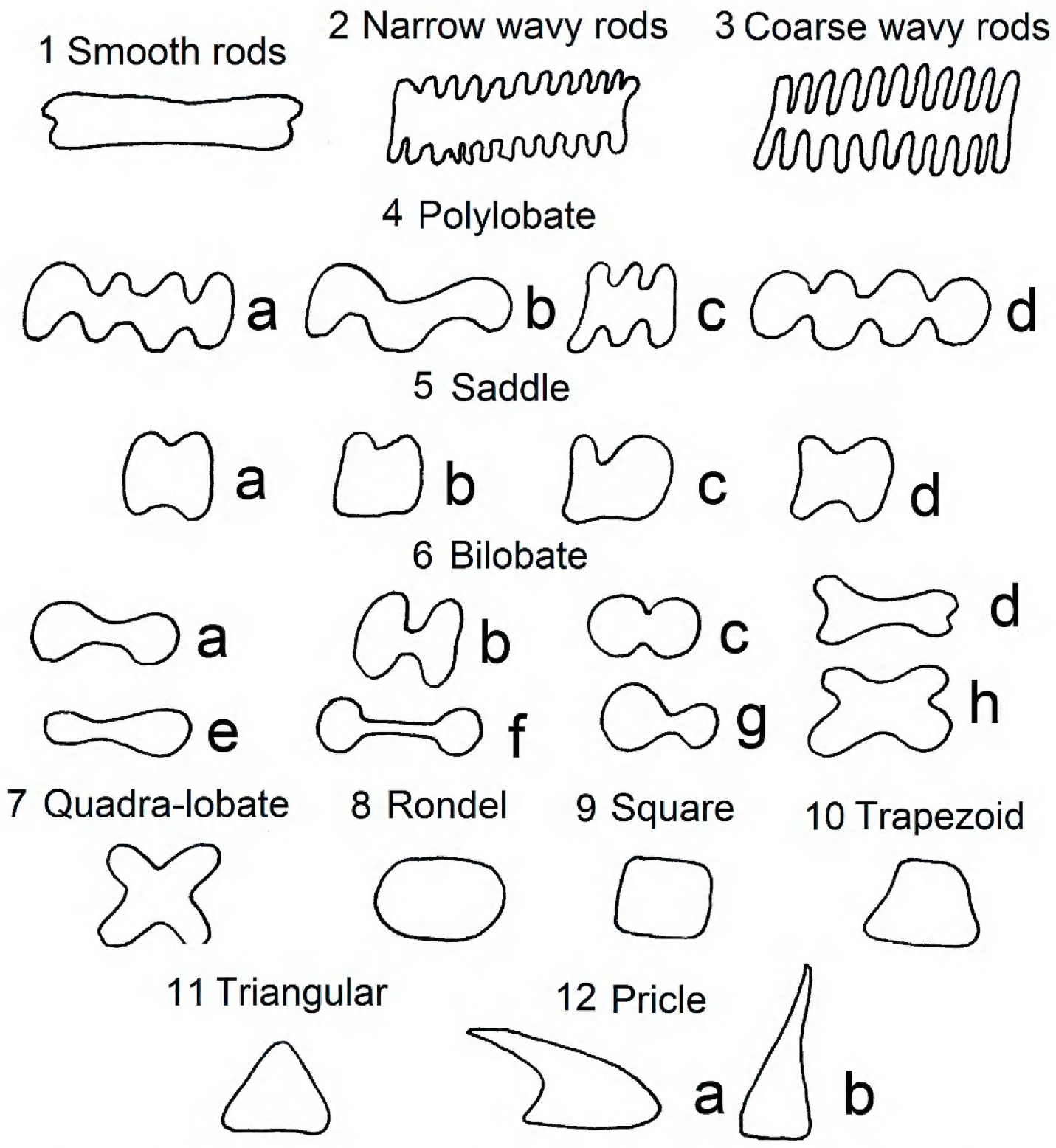

Figure 2. Morphological types of phytoliths from some grasses of arid lands of Xinjiang.

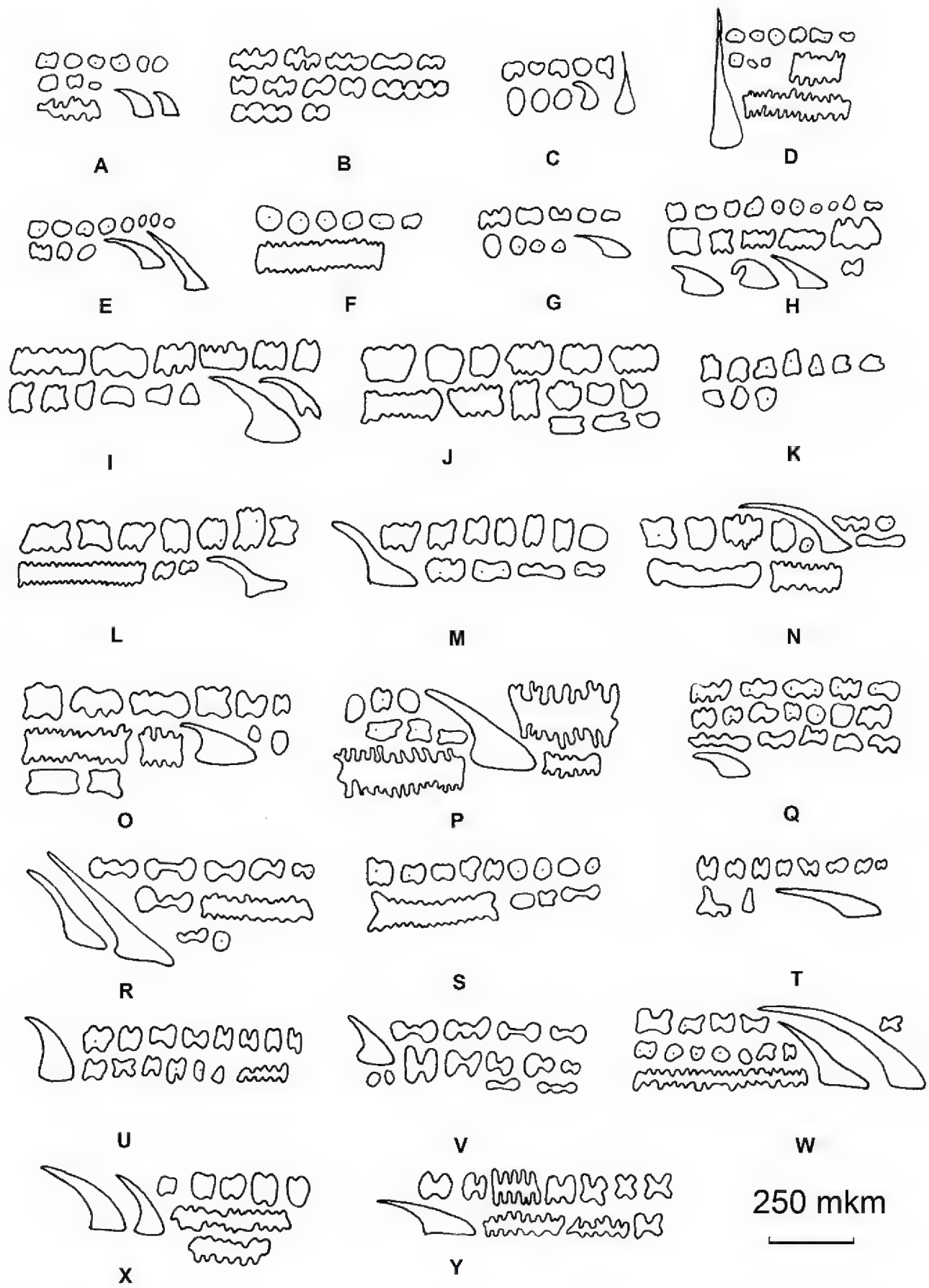

Figure 3. Morphological types of phytoliths from some grasses of arid lands of Xinjiang (scale line 250 mkm). **A** – *Stephanachne pappophorea*; **B** – *Piptatherum songaricum*; **C** – *Stipa sareptana*; **D** – *Stipa glareosa*; **E** – *Ptilagrostis pellioti*; **F** – *Achnatherum splendens*; **G** – *Achnatherum caragana*; **H** – *Melica transsilvanica*; **I** – *Polypogon monspeliensis*; **J** – *Bromus squarrosus*; **K** – *Leymus racemosus*; **L** – *Leymus secalinus*; **M** – *Psathyrostachys juncea*; **N** – *Kengyilia hirsuta*; **O** – *Kengyilia kokonorica*; **P** – *Eremopyrum bonaepartis*; **Q** – *Schismus arabicus*; **R** – *Aristida adscensionis*; **S** – *Stipagrostis pennata*; **T** – *Aeluropus micrantherus*; **U** – *Aeluropus pungens*; **V** – *Cleistogenes sqarrosa*; **W** – *Crypsis schoenoides*; **X** – *Chloris virgate*; **Y** – *Botriochloa ischaemum*.

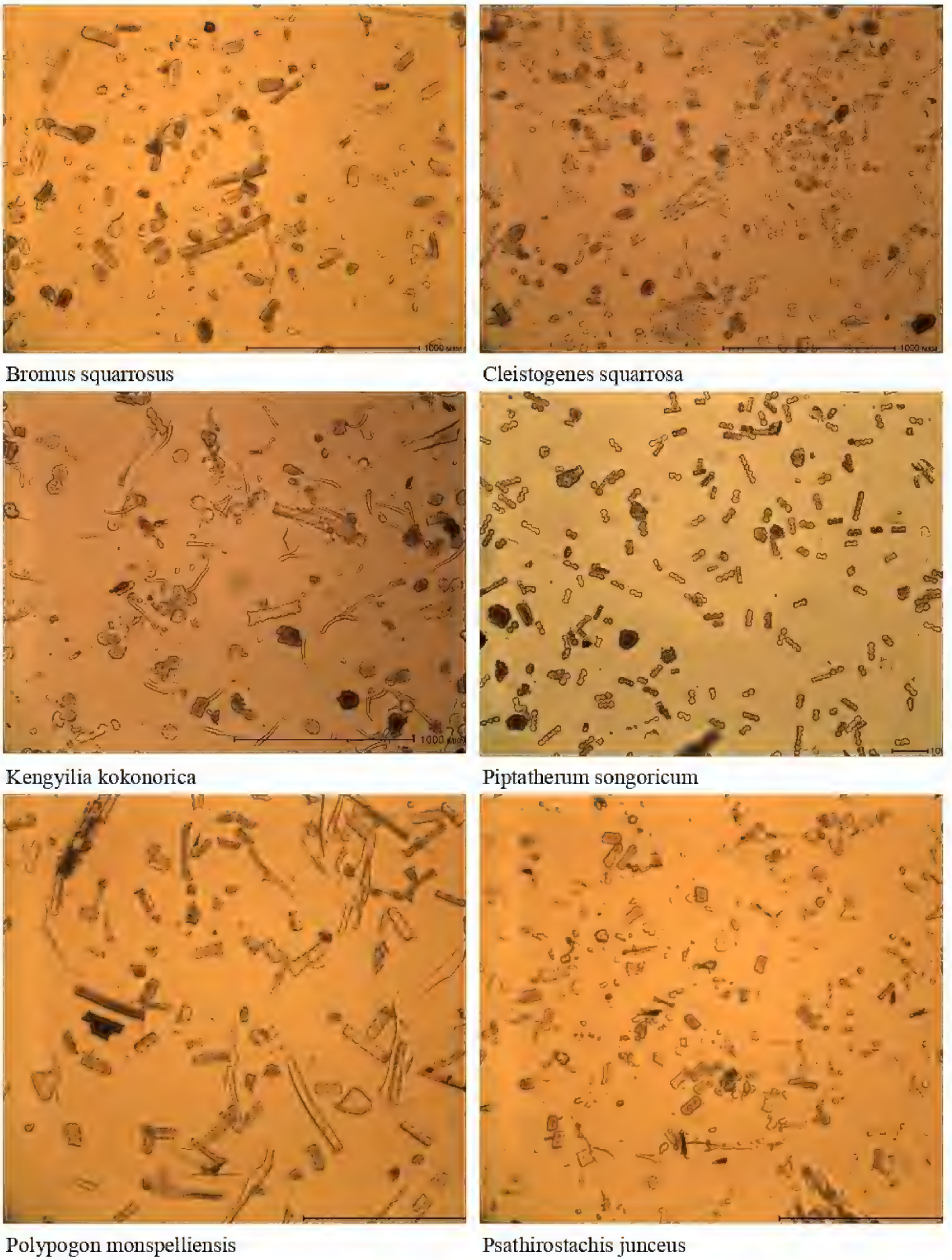

Figure 4. Phytoliths of some grasses of the arid area of Xinjiang.

Subfamily Pooideae Benth. is not only the best presented in this research, but also most various in taxonomic respect. The samples of 5 tribes, belonging to this subfamily, have been involved in this analysis (Table 1). The phytoliths, removed from these species, are very various and diverse (Figs 3, 4). There are notable distinctions in structure and proportion of phytoliths at a tribe level also.

Tribe Stipeae Dumort. seems to be the most singular among subfamily Pooideae, and in the shape of its silica cells, it is quite similar to subfamily Chloridoideae. It is the most noticeable at *Piptatherum songaricum*, whose phytoliths are presented by regular, bead-formed polylobate silica cells, which were then reduced to bilobate ones (Figs 3B, 4). The polylobate and bilobate phytoliths are not characteristic for subfamily Pooideae, nevertheless the similar cells occur at *Achnatherum caragana* (Fig. 3G), whereas, at the close species, *Achnatherum splendens* roundel (orbicular) silica cells, more typical for this subfamily, prevailed (Fig. 3F; Table 2).

In the tribe Triticeae Dumort., the most singular are the rod-formed phytoliths, resembling the narrow wavy rods (Figs 2, 3). They were revealed at *Eremopyrum bonaepartis* (Fig. 3P), *Kengyilia kokonorica* (Figs 3O, 4). The rod-formed silica cells of other species of this tribe had almost smooth walls – *Psathyrostachys juncea* (Figs 3M, 4). The different kinds of saddle cells are prevailing among the samples of this tribe. The original small silica cells, mainly trapezoid, have been revealed at *Leymus racemosus* (Fig. 3K), whereas the close species of *Leymus secalinus* had more various phytoliths, the rods and prickles to be among them (Fig. 3L).

Polypogon monspeliensis (Figs 3I, 4), *Bromus squarrosus* (Figs 3J, 4) and *Melica transsilvanica* (Fig. 3H) belonging, accordingly, to tribes Aveneae Dumort., Bromeae Dumort., and Meliceae Endl., have quite similar phytoliths, but among the last samples they are less similar in size.

Conclusion

This research has revealed the significant morphological diversity of phytoliths, and has also confirmed as a whole their taxonomic description, offered by Piperno (2006) at the level of subfamilies. Among the samples of subfamily Panicoideae, the bilobate and quadra-lobate silica cells are prevailing; the phytoliths of subfamily Pooideae are mainly roundel and trapezoid; trapezoid and saddle phytoliths are the most common among subfamily Chloridoideae. Subfamily Danthonioideae mainly has elongated silica cells with wavy walls. Bilobate, as well as roundel and square, phytoliths are characteristic for subfamily Aristidaideae. The elongated cells with smooth walls, which are common among the mesomorphic plants of meadows and forests (Olonova and Mezina 2011), were almost never found in investigated samples of arid and semiarid grasses of Xinjiang. Despite some deviations – some species of tribe Stipeae Dumort. (subfamily Pooideae) have proved to be quite similar in the shape of its silica cells to subfamily Chloridoideae. The phytoliths of *Cleistogenes squarrosa* (subfamily Chloridoideae) were represented mainly by various kinds of bilobate cells, instead of being mainly saddle.

Acquired data can be used for identification of phytoliths from sediments, but, since all other parts of grasses contain phytoliths, like leaf blades, they should also be investigated.

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